11/24/98 JC580 U.S. PTO

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PTO/SB/05 (12/97)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 42390.P6376 Total Pages 2

First Named Inventor or Application Identifier Tinku Acharya

Express Mail Label No. EL164804357US

JC525 U.S. PTO 09/199836 11/24/98

ADDRESS TO: **Assistant Commissioner for Patents**
Box Patent Application
Washington, D. C. 20231

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents.

1. X Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)

2. X Specification (Total Pages 18)
(preferred arrangement set forth below)
- Descriptive Title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings (if filed)
- Detailed Description
- Claims
- Abstract of the Disclosure

3. X Drawings(s) (35 USC 113) (Total Sheets 8)

4. X Oath or Declaration (Total Pages 6)
   a. ___ Newly Executed (Original or Copy)
   b. ___ Copy from a Prior Application (37 CFR 1.63(d))
   (for Continuation/Divisional with Box 17 completed) **(Note Box 5 below)**
   i. ___ DELETIONS OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

5. _ Incorporation By Reference (useable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. _ Microfiche Computer Program (Appendix)

7. _ Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
   a. ____ Computer Readable Copy
   b. ____ Paper Copy (identical to computer copy)
   c. ____ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. ____ Assignment Papers (cover sheet & documents(s))
9. ____ a. 37 CFR 3.73(b) Statement (where there is an assignee)
   ____ b. Power of Attorney
10. ____ English Translation Document (if applicable)
11. _X_ a. Information Disclosure Statement (IDS)/PTO-1449
    _X_ b. Copy of IDS Citation
12. ____ Preliminary Amendment
13. _X_ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
14. ____ a. Small Entity Statement(s)
    ____ b. Statement filed in prior application, Status still proper and desired
15. ____ Certified Copy of Priority Document(s) (if foreign priority is claimed)

16. Other: ________________

17. **If a CONTINUING APPLICATION,** check appropriate box and supply the requisite information:
___ Continuation ___ Divisional ___ Continuation-in-part (CIP)
of prior application No: ________________

18. **Correspondence Address**

____ Customer Number or Bar Code Label ________________
(Insert Customer No. or Attach Bar Code Label here)

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Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

FEE TRANSMITTAL

TOTAL AMOUNT OF PAYMENT ($) 1528.00

Complete if Known:
Application No. ____________
Filing Date ____________
First Named Inventor Tinku Acharya
Group Art Unit ____________
Examiner Name ____________
Attorney Docket No. 42390.P6376

METHOD OF PAYMENT (check one)

1. [ ] The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

   Deposit Account Number 02-2666
   Deposit Account Name ____________

   [X] Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17

   [ ] Charge the Issue Fee Set in 37 CFR 1.18 at the Mailing of the Notice of Allowance, 37 CFR 1.131(b)

2. X Payment Enclosed
   X Check
   ___ Money Order
   ___ Other

FEE CALCULATION (fees effective 10/01/97)

1. FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	790	201	395	Utility application filing fee	$790.00
106	330	206	165	Design application filing fee	
107	540	207	270	Plant filing fee	
108	790	208	395	Reissue filing fee	
114	150	214	75	Provisional application filing fee	

SUBTOTAL (1) $ 790.00

2. CLAIMS

			Extra		Fee from below		Fee Paid
Total Claims	16	− 20 =	0	X		=	
Independent Claims	12	− 3 =	9	X	$82.00	=	$738.00
Multiple Dependent Claims			0		X	=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
103	22	203	11	Claims in excess of twenty	
102	82	202	41	Independent claims in excess of 3	$738.00
104	270	204	135	Multiple dependent claim	
109	82	209	41	Reissue independent claims over original patent	
110	22	210	11	Reissue claims in excess of 20 and over original patent	

SUBTOTAL (2) $ 738.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for response within first month	
116	400	216	200	Extension for response within second month	
117	950	217	475	Extension for response within third month	
118	1,510	218	755	Extension for response within fourth month	
128	2,060	228	1,030	Extension for response within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive unavoidably abandoned application	
141	1,320	241	660	Petition to revive unintentionally abandoned application	
142	1,320	242	660	Utility issue fee (or reissue)	
143	450	243	225	Design issue fee	
144	670	244	335	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	790	246	395	For filing a submission after final rejection (see 37 CFR 1.129(a))	
149	790	249	395	For each additional invention to be examined (see 37 CFR 1.129(a))	

Other fee (specify) ______________________ ________

Other fee (specify) ______________________ ________

SUBTOTAL (3)$ 0

*Reduced by Basic Filing Fee Paid

SUBMITTED BY:

Typed or Printed Name: James H. Salter

Signature [signature] Date 11/24/98

Reg. Number 35,668 Deposit Account User ID ________

(complete if applicable)

Application for United States Letters Patent

for

Color Interpolation for a Four Color Mosaic Pattern

by

Tinku Acharya

Edward J. Bawolek

Ping-Sing Tsai

and

John J. Bean

"Express Mail" mailing label number: EL164804357US
Date of Deposit: November 24, 1998
I hereby certify that I am causing this paper or fee to be deposited with the United States Postal Service "Express Mail Post Office to Addressee" service on the date indicated above and that this paper or fee has been addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231

Cindy Murphy
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Cindy Murphy
(Signature of person mailing paper or fee)

11/24/98
(Date Signed)

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Field of Invention

The present invention relates to imaging, and more particularly, to a four-color mosaic tiling pattern and color interpolation.

Background

A simplified cross sectional view of an imaging system is illustrated in Fig. 1. Optical system **102** focuses electromagnetic radiation onto a focal plane, which may be taken as Color Filter Array (CFA) **104** and pixel sensor array **106**. The CFA is usually deposited over pixel sensor array **106** by photo-lithographic techniques well known to the semiconductor industry. Pixel sensor array **106** is an array of pixel sensors, where in general, a pixel sensor is any sensor which absorbs radiation and provides a signal indicative of the absorbed radiation. Pixel sensor array **106** may be, for example, an array of charge coupled devices (CCD), or an integrated array of CMOS (Complementary Metal Oxide Semiconductor) pixel circuits. A pixel circuit may comprise a photo diode, where photons absorbed by the photo diode generate electron-hole pairs, along with additional circuits to provide an electrical signal, either a voltage or current signal, indicative of the number of photons absorbed by the photo diode. Photons incident upon various pixel circuits are pictorially indicated by **108**.

The spectral content of electromagnetic radiation focused onto a focal plane depends upon, among other things, the imaged subject, the illumination of the subject, the transmission characteristics of the propagation path between the imaged subject and optical system **102**, the materials used in optical system **102**, as well the geometric shape and size of optical system **102**. For consumer imaging systems, the spectral range of interest is the visible region of the electromagnetic spectrum.

The CFA is an array of filters, usually contiguous and deposited over pixel sensor array **106** so that each pixel sensor is substantially sensitive to only the electromagnetic radiation passed by one filter. (A filter in the CFA may actually be a composite filter manufactured from two or more filters, so that the transfer function of the resulting filter is the product of the transfer functions of its constituent filters.) Each filter in the CFA passes electromagnetic radiation within some spectral range. For example, a CFA may be

composed of red, green, and blue filters, so that the pixel sensors may provide signals indicative of the visible color spectrum.

If there is not an infrared blocking element somewhere in the optical chain, then infrared radiation (IR), typically considered to be light with a wavelength longer than 780 nm, may also be focused upon the focal plane. Imaging sensors or devices based on silicon technology typically require the use of infrared blocking elements to prevent IR from entering the imaging array. Silicon-based devices will typically be sensitive to light with wavelengths up to approximately 1200 nm. If the IR is permitted to enter the array, the device will respond to the IR, and generate an output image signal. Since the purpose of an imaging system (in this context) is to create a representation of the visible light present in a scene, the IR may introduce a false response and distort the image. In a monochrome (black and white) imaging system, the result may be an obviously distorted rendition. For example, foliage and human skin tones may appear unusually light. In a color imaging system, the introduction of IR may distort the coloration and produce an image with incorrect and de-saturated color.

A common method for preventing these difficulties is to use ionically colored glass or a thin-film optical coating on glass to create an optical element which passes visible light (typically from 380 nm to 780 nm) and blocks the IR. This element can be placed in front of the taking lens, located within the lens system, or it can be incorporated into the imager package. The principle disadvantages to this approach are cost and added system complexity.

An alternative approach is to allow IR to enter the focal plane, and then remove the IR signal electronically. In this approach, the CFA will have some IR pass filters (which also substantially block visible light), and the pixel sensor array would have some pixel sensors responsive to IR only. The effect of IR upon an image signal is substantially reduced by electronically subtracting signals generated by IR pixel sensors from signals generated by pixel sensors responsive to both IR and visible light.

It is therefore desirable to provide for a CFA with a suitable arrangement of IR and visible color filters, and to provide for a method of processing the resulting pixel signals to obtain proper color interpolation without the need of an IR blocking filter.

Brief Description of the Drawings

Fig. 1 illustrates a simplified cross sectional view of an imaging system.

Fig. 2 is a unit array of a four color mosaic pattern for the RGB color space.

Fig. 3 is a circuit diagram of a pixel sensor.

Fig. 4 is a signal timing diagram for the pixel sensor circuit of Fig. 3.

Fig. 5 is a flow diagram for color component signal interpolation.

Fig. 6 is a unit array of a four color mosaic pattern.

Fig. 7 is a block diagram of a computer system to perform color interpolation.

Fig. 8 is a unit aray of a four color mosaice pattenr for the CMY color space.

Detailed Description of Embodiments

A four color Red-Green-Blue-InfraRed (R-G-B-IR) tiling pattern for a CFA is described in which the ratio of green, red, blue, and IR filters is approximately 4:1:1:2. (It may be approximate due to "edge" effects in the deposition of the CFA.) Fig. 2 illustrates a unit array of a tiling pattern according to an embodiment of the present invention, where R, G, B, and IR, denote read, green, blue, and IR pass filters, respectively. The tiling pattern is provided by repeating the unit array of Fig. 2 in both the row and column directions. The number of repetitions may be non-integral. For convenience, we shall refer to IR as a color, so that the tiling pattern based upon the unit array of Fig. 2 is a four-color mosaic pattern. It is also to be understood that the R, G, and B pass filters may also each pass IR.

It is to be appreciated that the designations of rows and columns is arbitrary, and that the pattern of filters in Fig. 2 may be rotated about a perpendicular to the figure. For notational simplicity, we shall denote a pixel sensor as red, green, blue, or IR, if it is responsive to substantially only electromagnetic radiation passed by a red, green, blue, or IR pass filter, respectively.

Let $X(n,m)$ denote the output signal of a pixel sensor responsive to the pass filter of row-column position (n,m). The output signal may, for example, be a voltage or a current. An embodiment of a pixel sensor circuit in which the output signal is a voltage is shown in Fig. 3, where the pixel sensor circuit comprises pixel diode **305** and associated circuitry. Photons captured by diode **305** are measured in the following way. A reset

voltage signal goes HIGH to switch nMOSFET **310** ON so that diode **305** is reverse biased to a reverse bias voltage V_{cc}. This creates a wide depletion layer within diode **305**. While reset voltage signal is HIGH, a shutter voltage signal also is set HIGH to switch nMOSFET **315** ON so that capacitor **320** is charged to the reverse bias voltage of diode **305**. When diode **305** is impacted by a photon with sufficient energy, the photon generates an electron-hole pair. If the reset voltage signal is brought LOW so that nMOSFET **310** is OFF but the shutter voltage signal is still HIGH, then electron-hole pairs generated by photons captured in diode **305** discharge diode's **305** parasitic capacitance, reducing diode's **305** reverse bias voltage and similarly reducing the voltage stored on capacitor **320**. The length of time for which the shutter voltage signal is HIGH and the reset voltage signal is LOW determines the integration time. In one embodiment, diode **305** is initially biased to approximately 2.3 volts.

Fig. 4 illustrates various signals related to Fig. 3. In Fig. 4, the reset and shutter voltage signals are HIGH during time segment A-B, whereas the reset voltage signal is OFF during time segment B-C but the shutter voltage signal is HIGH. Time segment B-C represents the integration time. During the integration time, the voltage at the cathode of diode **305** and the voltage of capacitor **320** are decaying due to the generation of electron-hole pairs. After the shutter voltage signal goes LOW at time C, the cathode voltage of diode **305** continues to decay, but the voltage of capacitor **320** stays approximately constant. The voltage difference denoted by V_{image} in Fig. 4, which is the difference between the initial and final voltages of capacitor **320**, represents the time integration of the intensity of light captured by pixel diode **305** during a frame time.

To determine V_{image}, the voltage of capacitor **320** needs to be read when diode **305** is fully reverse biased (when the reset voltage signal is HIGH) and when the shutter voltage signal returns LOW. The voltage of capacitor **320** is read at the source of nMOSFET **325**, where nMOSFET **325**, current mirror nMOSFETs **330**, and current source **335** comprise a follower. The source voltage of nMOSFET **325** is read by switching a row address voltage signal HIGH so that nMOSFETs **340** are ON. If column line **345** is properly discharged before the row address voltage signal is HIGH, then the voltage on column line **345** is to within a threshold voltage drop of the voltage of

capacitor **320**. Not shown in Fig. 3 are other column pixels coupled to column line **345** and identical in structure to that shown in Fig. 3.

The row address voltage signal is shown in Fig. 4. By setting the row address voltage signal HIGH during the time segment A-B, the source voltage of nMOSFET **325** is read when capacitor **320** is fully charged, and by setting the row address voltage signal HIGH during the time segment C-F (but not at time F) the source voltage of nMOSFET **325** is read when capacitor **320** is discharged after the integration time. The former and latter read source voltages provide calibration and sample voltage signals, respectively. If dark voltage was not present, then V_{image} would be an accurate representation of the time integration of the light intensity incident upon pixel diode **305**. Subtracting the sample voltage signal from the calibration voltage signal compensates for pixel-to-pixel variation, such as differences in threshold voltages for the source follower transistors (nMOSFET **325**).

Fig. 3 is only one representative example of a pixel sensor. The output signals from the pixel sensors are processed to obtain interpolated red, green, and blue color component signals. Let $R(n,m)$, $G(n,m)$, and $B(n,m)$ denote, respectively, interpolated red, green, and blue color component signals for row-column position (n,m).

A method for providing the interpolated color component signals for the tiling pattern of Fig. 2 can be concisely described by introducing the notation that an index *i* for which *i* = 1, 2, or 3, denotes, respectively, red, blue, or green. As an example of this notation, let $\hat{X}_i(n,m)$ denote an interpolated color component signal, where $\hat{X}_1(n,m) = R(n,m)$, $\hat{X}_2(n,m) = G(n,m)$, and $\hat{X}_3(n,m) = B(n,m)$. A method for providing the interpolated color component signals for the tiling pattern of Fig. 2 is now described as follows: For a position (n,m), pixel sensor output signal $X(n,m)$, and for each *i* = 1, 2, 3, if $X(n,m)$ is an output signal of a color *i* pixel sensor, then $\hat{X}_i(n,m) = X(n,m)$, and if $X(n,m)$ is an output signal of an IR pixel sensor or a color $j \neq i$ pixel sensor, then $\hat{X}_i(n,m)$ is an average of the output signals of nearest neighbor color *i* pixel sensors.

Fig. 5 provides a flow diagram of the above method. In step **502**, the averaging is understood to be over nearest neighbor pixel sensor positions having color i. To illustrate examples, refer to Fig. 6, which is the tiling pattern of Fig. 2 extended to have five rows. The rows and columns in Fig. 6 are indexed as shown for convenience only. As an example of nearest neighbor averaging, consider position (2,2) in Fig. 6. This is an IR pass filter. A set of interpolated color signal components is:

$$R(2,2) = \frac{X(1,3)+X(3,1)}{2},$$
$$G(2,2) = \frac{X(1,2)+X(2,1)+X(3,2)+X(2,3)}{4}.$$
$$B(2,2) = \frac{X(1,1)+X(3,3)}{2}.$$

As another example, consider position (3,3) in Fig. 6. This is a blue pass filter. A set of interpolated color signal components is:

$$R(3,3) = \frac{X(1,3)+X(5,3)}{2},$$
$$G(3,3) = \frac{X(2,3)+X(3,2)+X(3,4)+X(4,3)}{4},$$
$$B(3,3) = X(3,3).$$

For another example, consider position (3,2) in Fig. 6. This is a green pass filter. A set of interpolated color signal components is:

$$R(3,2) = X(3,1),$$
$$G(3,2) = X(3,2),$$
$$B(3,2) = X(3,3).$$

The above sums and divisions in the above displayed equations are to be interpreted as operations performed in either the analog or digital domain. In general, the averaging of signals over nearest neighbors is approximate because of finite wordlengths, if performed in the digital domain, or the inherent approximate nature of performing operations in the analog domain. Furthermore, the interpolated signals need only be proportional (or approximately) proportional to an average. For example, the right-hand-sides of the above displayed equations may be multiplied by a proportionality factor.

The averaging operations may be performed by non-programmed hardwired circuits (either analog or digital), by circuits programmed by firmware (software stored in

non-volatile memory), by a computer, or any combination of such methods. For example, a simplified computer system is illustrated in Fig. 7. In the embodiment of Fig. 7, processor **702** performs the nearest neighbor averaging indicated in step **502** of Fig. 5, where the software code for performing this averaging is stored in memory **704**. In Fig. 7, camera provides image data to processor **702**. Video interface circuit **708**, which for some embodiments may not be needed, provides for communication between processor **702** and camera **706** via bus **710**. As one alternative to the embodiment of Fig. 7, pixel averaging may be performed by circuits within camera **706**.

Returning to Fig. 5, in step **504**, the indices n and m are changed and new interpolated color component signals are interpolated for a new position (n,m). The processing indicated by Fig. 5 may be performed on the pixel sensor positions in a sequential manner, or more than one position may be processed in parallel.

The output signals from the IR pixel sensors may be used to subtract the IR components from the $\hat{X}_i(n,m)$. For example, an interpolated IR signal component for position (n,m) may be obtained by taking the average of the output signals from the nearest IR pixel sensors, and subtracting this interpolated IR signal from the interpolated color component signals. For some embodiments, this processing may be performed by processor **702**.

The IR pass filters may be manufactured using commercial Color Filter Array (CFA) materials, taking advantage of the fact that these materials are transparent to IR radiation. By a simple overlay of two CFA colors (e.g., R and B pass filters) that have no overlapping transmittance in the visible portion of the spectrum, it is possible to create a composite filter element that blocks the visible light and transmits only IR. If two filters are used to form the composite filter, then each of the two filters has a visible radiation pass spectrum that is disjoint from the other, so that there is substantially no transmittance of visible light through the resulting composite filter formed from the combination of the two filters. If more than two filters are used, then each filter has a visible radiation pass spectrum such that the resulting composite filter is substantially opaque to visible light. This composite filter element is thus an IR pass filter, because each of the component filters used to form the composite filter is substantially transparent to IR.

Another embodiment of the present invention for the CMY (Cyan- Magenta-Yellow) color space is provided in Fig. 8. Fig. 8 denotess a unit array of filters for a tiling pattern, where filters designated by C, Y, and M denote pass filters for the colors cyan, yellow, and magenta, respectively. Note that the unit array of Fig. 8 corresponds ot the unit array of Fig. 2 by making the correspondances: C $\leftrightarrow$ B, Y $\leftrightarrow$ G, and M $\leftrightarrow$ R.

Fig. 5 provides a flow diagram for pixel interpolation with the CMY tiling pattern of Fig. 8, where now $M(n,m)$, $Y(n,m)$, and $C(n,m)$ denote, respectively, interpolated magenta, yellow, and cyan color component signals for row-column position (n,m), and now $\hat{X}_i(n,m)$ denotes an interpolated color component signal where

$\hat{X}_1(n,m) = M(n,m)$, $\hat{X}_2(n,m) = Y(n,m)$, and $\hat{X}_3(n,m) = C(n,m)$.

It is to be understood that in some embodiments, not all interpolated color component signals need be obtained by averaging signals from nearest neighbors with like colors. For example, signals from pixel sensors at the edge of the CFA may be processed differently. Or, only a proper subset of the signal outputs from the pixel sensors may be interpolated. Many modifications may be made to the above disclosed embodiments, and the invention is limited only by the scope of the claims below.

What is claimed is:

1. A color filter array comprising a unit array, the unit array having green, red, blue, and infrared pass filters in the relative ratios of 4:1:1:2, respectively.

2. A color filter array comprising:

a first row of pass filters, comprising, in order, blue, green, red, and green pass filters;

a second row of pass filters, comprising, in order, green, infrared, green, and infrared pass filters, wherein the second row of pass filters is adjacent to the first row of pass filters so that the blue pass filter of the first row is adjacent to the first green pass filter of the second row;

a third row of pass filters, comprising, in order, red, green, blue, and green pass filters, wherein the first green pass filter of the second row is adjacent to the red pass filter of the third row; and

a fourth row of pass filters, comprising, in order, green, infrared, green, and infrared pass filters, wherein the red pass filter of the third row is adjacent to the first green pass filter of the fourth row.

3. A color filter array comprising an array of pass filters $f_{i,j}$ wherein for some n and m:

$f_{n+1,m+1}$ and $f_{n+3,m+3}$ are blue pass filters;

$f_{n+1,m+2}$, $f_{n+1,m+4}$, $f_{n+2,m+1}$, $f_{n+2,m+3}$, $f_{n+3,m+2}$, $f_{n+3,m+4}$, $f_{n+4,m+1}$, and $f_{n+4,m+3}$ are green pass filters;

$f_{n+1,m+3}$ and $f_{n+3,m+1}$ are red pass filters; and

$f_{n+2,m+2}$, $f_{n+2,m+4}$, $f_{n+4,m+2}$, and $f_{n+4,m+4}$ are infrared pass filters.

4. An imaging system comprising:

a color filter array comprising an array of pass filters f wherein for some n and m:

$f_{n+1,m+1}$ and $f_{n+3,m+3}$ are blue pass filters;

$f_{n+1,m+2}, f_{n+1,m+4}, f_{n+2,m+1}, f_{n+2,m+3}, f_{n+3,m+2}, f_{n+3,m+4}, f_{n+4,m+1}$, and $f_{n+4,m+3}$ are green pass filters;

$f_{n+1,m+3}$ and $f_{n+3,m+1}$ are red pass filters;

$f_{n+2,m+2}, f_{n+2,m+4}, f_{n+4,m+2}$, and $f_{n+4,m+4}$ are infrared pass filters; and

an array of pixel sensors responsive to electromagnetic radiation propagating through the color filter array, wherein for some range of position indices *u* and *v*, a pixel sensor at position (u,v) provides an output signal $X(u,v)$ indicative of electromagnetic radiation propagating through the color filter array and impinging upon the pixel sensor at position (u,v).

5. The imaging system as set forth in claim 4, further comprising

at least one processor to provide interpolated color component signals $\hat{X}_i(u,v)$, $i = 1, 2, 3$, where $i = 1$ denotes red, $i = 2$ denotes green, and $i = 3$ denotes blue, wherein for each $i = 1, 2, 3$; if $X(u,v)$ is an output signal of a color *i* pixel sensor, then $\hat{X}_i(u,v) = X(u,v)$, and if $X(u,v)$ is an output signal of an IR pixel sensor or a color $j \neq i$ pixel sensor, then $\hat{X}_i(u,v)$ is an average of the output signals of nearest neighbor color *i* pixel sensors.

6. The imaging system as set forth in claim 4, further comprising

a memory storage device, wherein stored in the memory storage device are instructions to process interpolated color component signals $\hat{X}_i(u,v)$, $i = 1, 2, 3$, where $i = 1$ denotes red, $i = 2$ denotes green, and $i = 3$ denotes blue, wherein for each $i = 1, 2, 3$; if $X(u,v)$ is an output signal of a color *i* pixel sensor, then $\hat{X}_i(u,v) = X(u,v)$, and if $X(u,v)$ is an output signal of an IR pixel sensor or a color $j \neq i$ pixel sensor, then $\hat{X}_i(u,v)$ is an average of the output signals of nearest neighbor color *i* pixel sensors.

7. A method to interpolate color component signals, comprising:

providing a color filter array comprising

a first row of pass filters, comprising, in order, blue, green, red, and green pass filters;

a second row of pass filters, comprising, in order, green, infrared, green, and infrared pass filters, wherein the second row of pass filters is adjacent to the first row of pass filters so that the blue pass filter of the first row is adjacent to the first green pass filter of the second row;

a third row of pass filters, comprising, in order, red, green, blue, and green pass filters, wherein the first green pass filter of the second row is adjacent to the red pass filter of the third row; and

a fourth row of pass filters, comprising, in order, green, infrared, green, and infrared pass filters, wherein the red pass filter of the third row is adjacent to the first green pass filter of the fourth row;

providing an array of pixel sensors responsive to electromagnetic radiation propagating through the color filter array, wherein for some range of position indices u and v, a pixel sensor at position (u,v) provides an output signal $X(u,v)$ indicative of electromagnetic radiation propagating through the color filter array and impinging upon the pixel sensor at position (u,v); and

interpolating to provide interpolated color component signals $\hat{X}_i(u,v)$, $i = 1, 2, 3$, where $i = 1$ denotes red, $i = 2$ denotes green, and $i = 3$ denotes blue, wherein for each $i = 1, 2, 3$; if $X(u,v)$ is an output signal of a color i pixel sensor, then $\hat{X}_i(u,v) = X(u,v)$, and if $X(u,v)$ is an output signal of an IR pixel sensor or a color $j \neq i$ pixel sensor, then $\hat{X}_i(u,v)$ is an average of the output signals of nearest neighbor color i pixel sensors.

8. A method to interpolate color component signals, comprising:

providing a color filter array comprising

a color filter array comprising an array of pass filters f wherein for some n and m:

$f_{n+1,m+1}$ and $f_{n+3,m+3}$ are blue pass filters;

$f_{n+1,m+2}, f_{n+1,m+4}, f_{n+2,m+1}, f_{n+2,m+3}, f_{n+3,m+2}, f_{n+3,m+4}, f_{n+4,m+1}$, and $f_{n+4,m+3}$ are green pass filters;

$f_{n+1,m+3}$ and $f_{n+3,m+1}$ are red pass filters; and

$f_{n+2,m+2}, f_{n+2,m+4}, f_{n+4,m+2}$, and $f_{n+4,m+4}$ are infrared pass filters;

providing an array of pixel sensors responsive to electromagnetic radiation propagating through the color filter array, wherein for some range of position indices u and v, a pixel sensor at position (u,v) provides an output signal $X(u,v)$ indicative of electromagnetic radiation propagating through the color filter array and impinging upon the pixel sensor at position (u,v); and

interpolating to provide interpolated color component signals $\hat{X}_i(u,v)$, $i = 1, 2, 3$, where $i = 1$ denotes red, $i = 2$ denotes green, and $i = 3$ denotes blue, wherein for each $i = 1, 2, 3$; if $X(u,v)$ is an output signal of a color i pixel sensor, then $\hat{X}_i(u,v) = X(u,v)$, and if $X(u,v)$ is an output signal of an IR pixel sensor or a color $j \neq i$ pixel sensor, then $\hat{X}_i(u,v)$ is an average of the output signals of nearest neighbor color i pixel sensors.

9. A color filter array comprising a unit array, the unit array having yellow, magenta, cyan, and infrared pass filters in the relative ratios of 4:1:1:2, respectively.

10. A color filter array comprising:

a first row of pass filters, comprising, in order, cyan, yellow, magenta, and yellow pass filters;

a second row of pass filters, comprising, in order, yellow, infrared, yellow, and infrared pass filters, wherein the second row of pass filters is adjacent to the first row of pass filters so that the cyan pass filter of the first row is adjacent to the first yellow pass filter of the second row;

a third row of pass filters, comprising, in order, magenta, yellow, cyan, and yellow pass filters, wherein the first yellow pass filter of the second row is adjacent to the magenta pass filter of the third row; and

a fourth row of pass filters, comprising, in order, yellow, infrared, yellow, and infrared pass filters, wherein the magenta pass filter of the third row is adjacent to the first yellow pass filter of the fourth row.

11. A color filter array comprising an array of pass filters $f_{i,j}$ wherein for some n and m:

$f_{n+1,m+1}$ and $f_{n+3,m+3}$ are cyan pass filters;

$f_{n+1,m+2}, f_{n+1,m+4}, f_{n+2,m+1}, f_{n+2,m+3}, f_{n+3,m+2}, f_{n+3,m+4}, f_{n+4,m+1}$, and $f_{n+4,m+3}$ are yellow pass filters;

$f_{n+1,m+3}$ and $f_{n+3,m+1}$ are magenta pass filters; and

$f_{n+2,m+2}, f_{n+2,m+4}, f_{n+4,m+2}$, and $f_{n+4,m+4}$ are infrared pass filters.

12. An imaging system comprising:

a color filter array comprising an array of pass filters f wherein for some n and m:

$f_{n+1,m+1}$ and $f_{n+3,m+3}$ are cyan pass filters;

$f_{n+1,m+2}, f_{n+1,m+4}, f_{n+2,m+1}, f_{n+2,m+3}, f_{n+3,m+2}, f_{n+3,m+4}, f_{n+4,m+1}$, and $f_{n+4,m+3}$ are yellow pass filters;

$f_{n+1,m+3}$ and $f_{n+3,m+1}$ are magenta pass filters;

$f_{n+2,m+2}, f_{n+2,m+4}, f_{n+4,m+2}$, and $f_{n+4,m+4}$ are infrared pass filters; and

an array of pixel sensors responsive to electromagnetic radiation propagating through the color filter array, wherein for some range of position indices u and v, a pixel sensor at position (u,v) provides an output signal $X(u,v)$ indicative of electromagnetic radiation propagating through the color filter array and impinging upon the pixel sensor at position (u,v).

13. The imaging system as set forth in claim 12, further comprising

at least one processor to provide interpolated color component signals $\hat{X}_i(u,v)$, $i = 1, 2, 3$, where $i = 1$ denotes magenta, $i = 2$ denotes yellow, and $i = 3$ denotes cyan, wherein for each $i = 1, 2, 3$; if $X(u,v)$ is an output signal of a color i pixel sensor, then $\hat{X}_i(u,v) = X(u,v)$, and if $X(u,v)$ is an output signal of an IR pixel sensor or a color $j \neq i$ pixel sensor, then $\hat{X}_i(u,v)$ is an average of the output signals of nearest neighbor color i pixel sensors.

14. The imaging system as set forth in claim 12, further comprising

a memory storage device, wherein stored in the memory storage device are instructions to process interpolated color component signals $\hat{X}_i(u,v)$, $i = 1, 2, 3$, where $i = 1$ denotes magenta, $i = 2$ denotes yellow, and $i = 3$ denotes cyan, wherein for each $i = 1, 2, 3$; if $X(u,v)$ is an output signal of a color i pixel sensor, then $\hat{X}_i(u,v) = X(u,v)$, and if $X(u,v)$ is an output signal of an IR pixel sensor or a color $j \neq i$ pixel sensor, then $\hat{X}_i(u,v)$ is an average of the output signals of nearest neighbor color i pixel sensors.

15. A method to interpolate color component signals, comprising:

providing a color filter array comprising

a first row of pass filters, comprising, in order, cyan, yellow, magenta, and yellow pass filters;

a second row of pass filters, comprising, in order, yellow, infrared, yellow, and infrared pass filters, wherein the second row of pass filters is adjacent to the first row of pass filters so that the cyan pass filter of the first row is adjacent to the first yellow pass filter of the second row;

a third row of pass filters, comprising, in order, magenta, yellow, cyan, and yellow pass filters, wherein the first yellow pass filter of the second row is adjacent to the magenta pass filter of the third row; and

a fourth row of pass filters, comprising, in order, yellow, infrared, yellow, and infrared pass filters, wherein the magenta pass filter of the third row is adjacent to the first yellow pass filter of the fourth row;

providing an array of pixel sensors responsive to electromagnetic radiation propagating through the color filter array, wherein for some range of position indices u and v, a pixel sensor at position (u,v) provides an output signal $X(u,v)$ indicative of electromagnetic radiation propagating through the color filter array and impinging upon the pixel sensor at position (u,v); and

interpolating to provide interpolated color component signals $\hat{X}_i(u,v)$, $i = 1, 2, 3$, where $i = 1$ denotes magenta, $i = 2$ denotes yellow, and $i = 3$ denotes cyan, wherein for each $i = 1, 2, 3$; if $X(u,v)$ is an output signal of a color i pixel sensor, then $\hat{X}_i(u,v) = X(u,v)$, and if $X(u,v)$ is an output signal of an IR pixel sensor or a color $j \neq i$ pixel sensor, then $\hat{X}_i(u,v)$ is an average of the output signals of nearest neighbor color i pixel sensors.

16. A method to interpolate color component signals, comprising:

providing a color filter array comprising

a color filter array comprising an array of pass filters f wherein for some n and m:

$f_{n+1,m+1}$ and $f_{n+3,m+3}$ are cyan pass filters;

$f_{n+1,m+2}$, $f_{n+1,m+4}$, $f_{n+2,m+1}$, $f_{n+2,m+3}$, $f_{n+3,m+2}$, $f_{n+3,m+4}$, $f_{n+4,m+1}$, and $f_{n+4,m+3}$ are yellow pass filters;

$f_{n+1,m+3}$ and $f_{n+3,m+1}$ are magenta pass filters; and

$f_{n+2,m+2}$, $f_{n+2,m+4}$, $f_{n+4,m+2}$, and $f_{n+4,m+4}$ are infrared pass filters;

providing an array of pixel sensors responsive to electromagnetic radiation propagating through the color filter array, wherein for some range of position indices u and v, a pixel sensor at position (u,v) provides an output signal $X(u,v)$ indicative of

electromagnetic radiation propagating through the color filter array and impinging upon the pixel sensor at position (u,v); and

interpolating to provide interpolated color component signals $\hat{X}_i(u,v)$, $i = 1, 2, 3$, where $i = 1$ denotes magenta, $i = 2$ denotes yellow, and $i = 3$ denotes cyan, wherein for each $i = 1, 2, 3$; if $X(u,v)$ is an output signal of a color i pixel sensor, then $\hat{X}_i(u,v) = X(u,v)$, and if $X(u,v)$ is an output signal of an IR pixel sensor or a color $j \neq i$ pixel sensor, then $\hat{X}_i(u,v)$ is an average of the output signals of nearest neighbor color i pixel sensors.

Abstract

An imager with a four color mosaic pattern of red, green, blue, and infrared pass filters, where color component signals for a pixel are interpolated by averaging over nearest neighbor pixels.

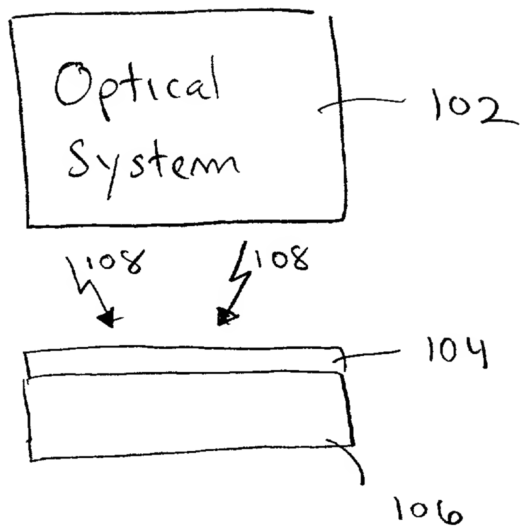


Fig. 1 Prior Art

B	G	R	G
G	IR	G	IR
R	G	B	G
G	IR	G	IR

Fig. 2.

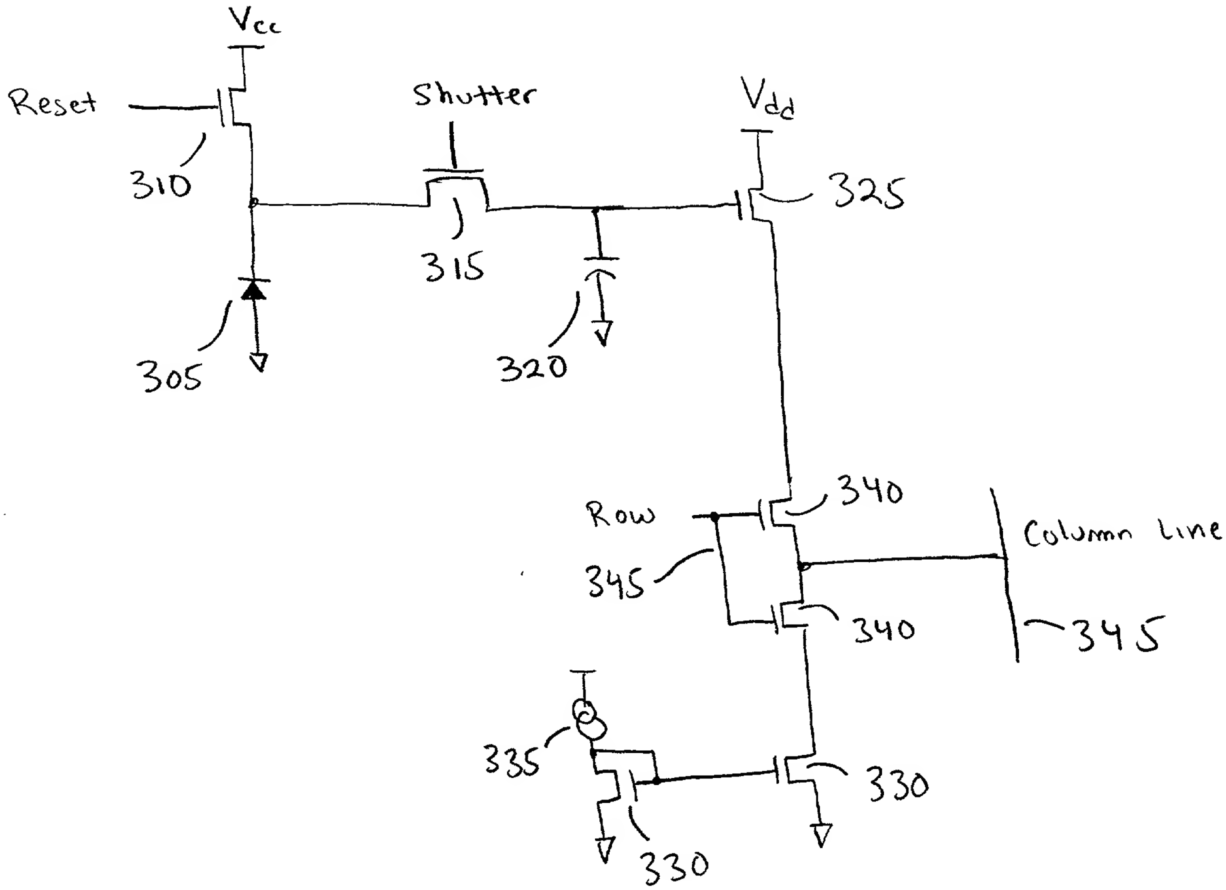

Vcc
Reset
310
Shutter
315
Vdd
325
305
320
Row
340
345
Column Line
340
345
335
330
330

Fig. 3

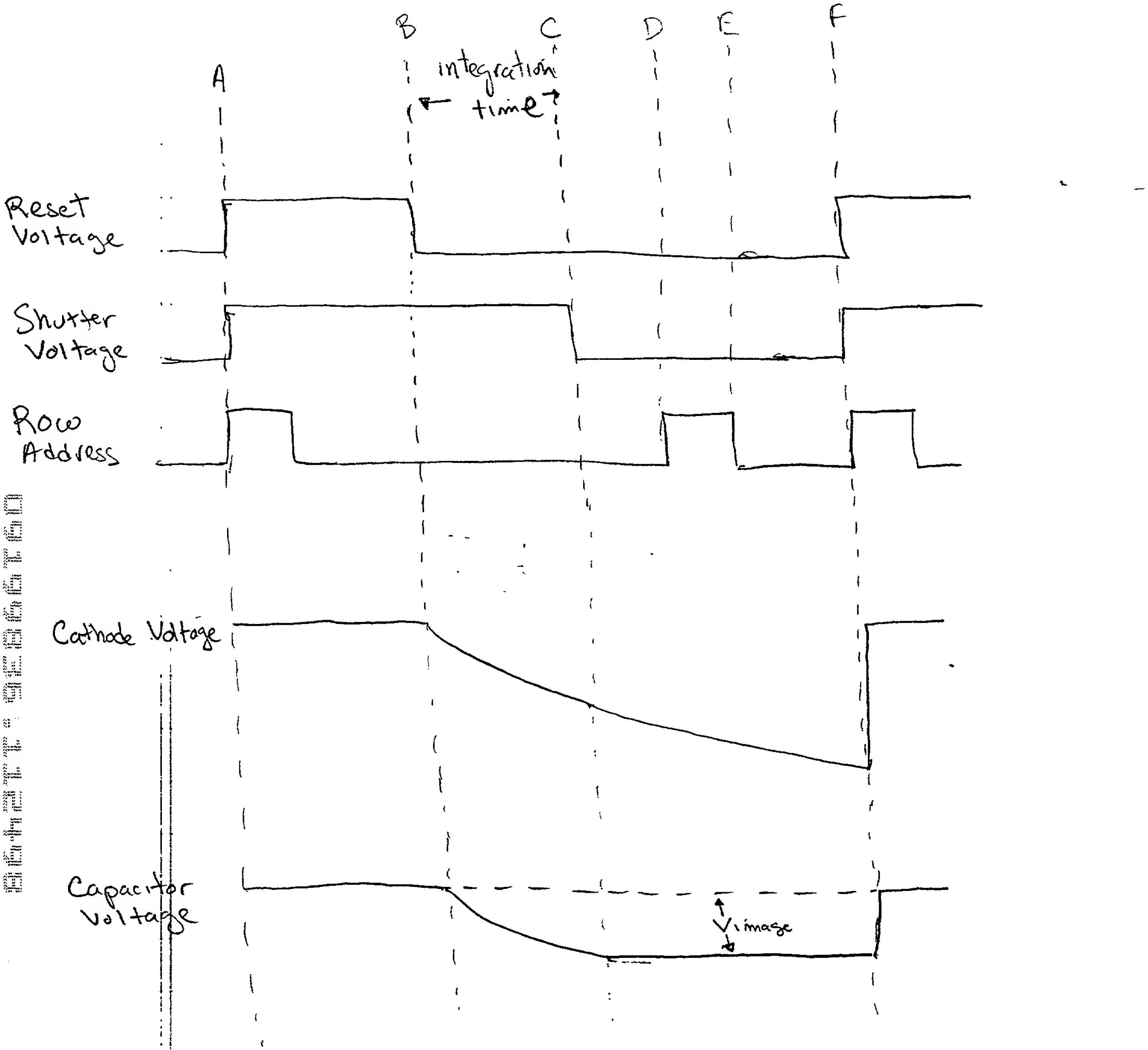
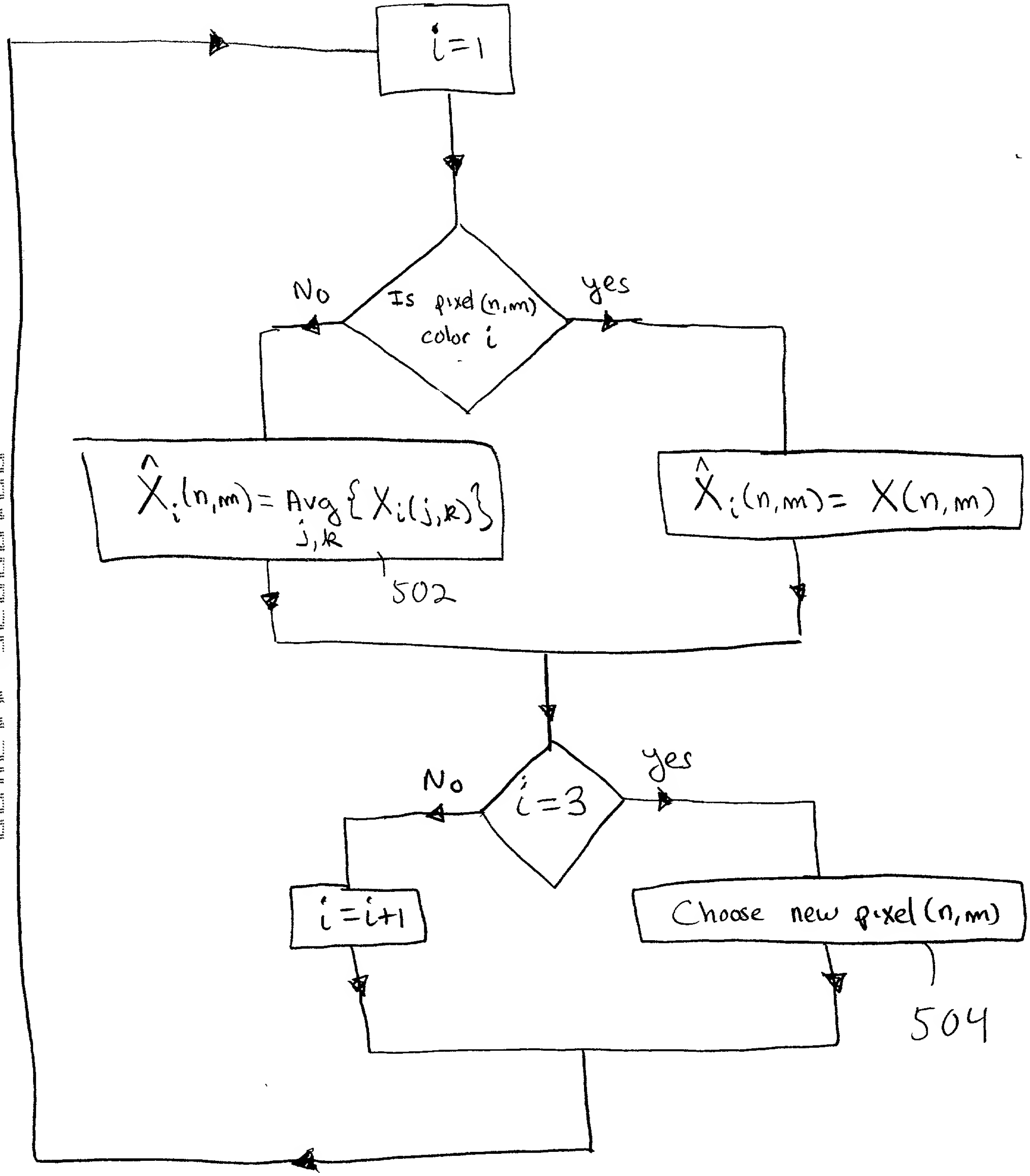

A
B
C
D
E
F
integration time
Reset Voltage
Shutter Voltage
Row Address
Cathode Voltage
Capacitor Voltage
V image

Fig. 4



$i=1$
Is pixel (n,m) color i
No
yes
$\hat{X}_i(n,m) = \mathrm{Avg}_{j,k}\{X_i(j,k)\}$
502
$\hat{X}_i(n,m) = X(n,m)$
$i=3$
No
yes
$i=i+1$
Choose new pixel (n,m)
504

Fig 5

	1	2	3	4
1	B	G	R	G
2	G	IR	G	IR
3	R	G	B	G
4	G	IR	G	IR
5	B	G	R	G

Fig. 6

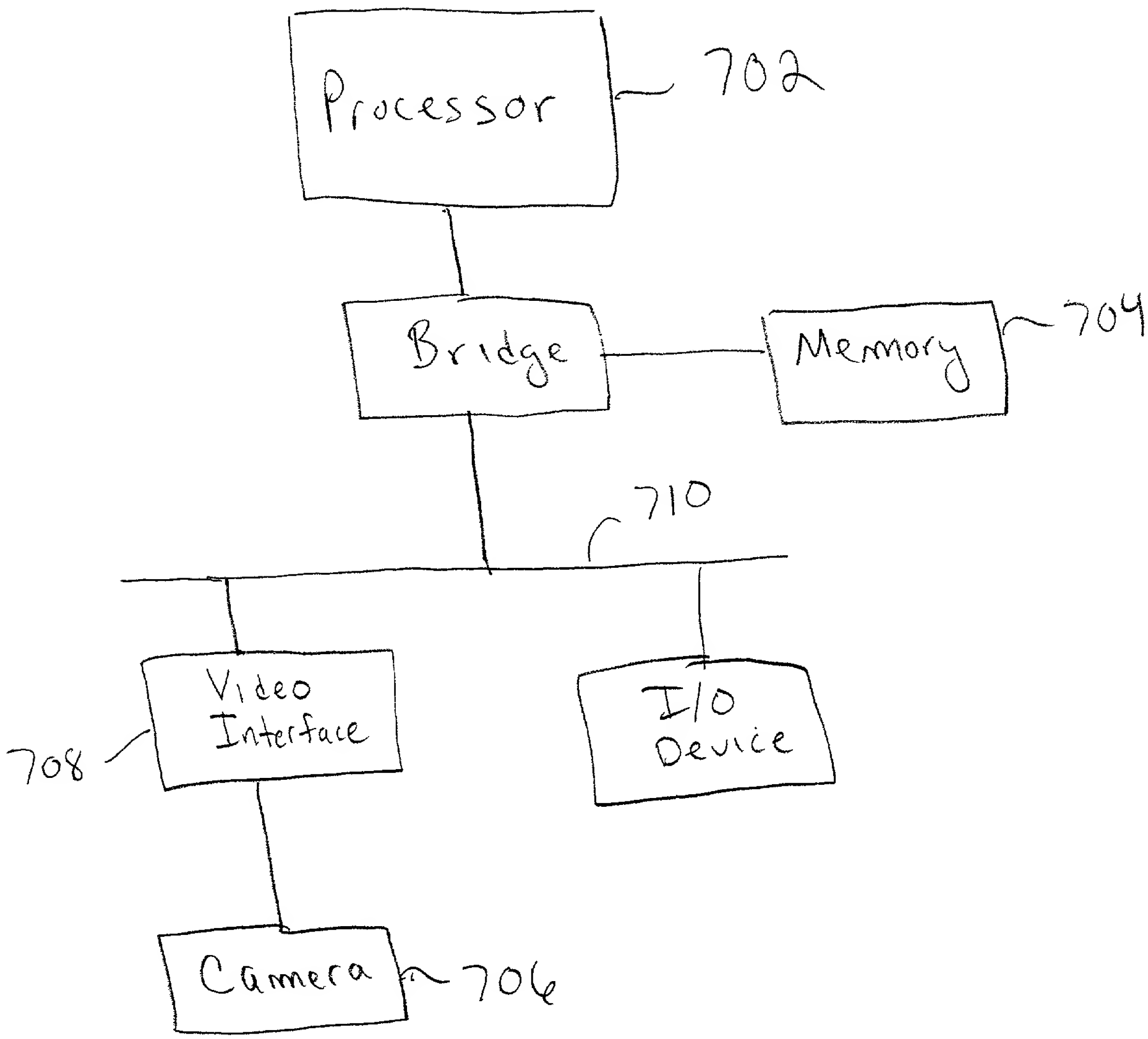

Processor
702
Bridge
Memory
704
710
Video Interface
708
I/O Device
Camera
706

Fig. 7

C	Y	M	Y
Y	IR	Y	IR
M	Y	C	Y
Y	IR	Y	IR

Fig. 8

Attorney's Docket No.: 42390.P6376 PATENT

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION
(FOR **INTEL CORPORATION** PATENT APPLICATIONS)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

COLOR INTERPOLATION FOR A FOUR COLOR MOSAIC PATTERN

the specification of which

XXX is attached hereto.
______ was filed on ____________________ as United States Application Number ______________ or PCT International Application Number______________ and was amended on ____________________.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No

I hereby claim the benefit under title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below

(Application Number)	Filing Date
(Application Number)	Filing Date

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Number)	Filing Date	(Status -- patented, pending, abandoned)
(Application Number)	Filing Date	(Status -- patented, pending, abandoned)

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Send correspondence to James H. Salter, BLAKELY, SOKOLOFF, TAYLOR &
(Name of Attorney or Agent)
ZAFMAN LLP, 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025 and direct telephone calls to James H. Salter, (408) 720-8598.
(Name of Attorney or Agent)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Inventor's Signature ____________________ Date ____________
Citizenship ____________
(Country)
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Full Name of Sole/Second Inventor **Edward J. Bawolek**
Inventor's Signature ____________________ Date ____________
Citizenship ____________
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Full Name of Sole/Third Inventor **Ping-Sing Tsai**
Inventor's Signature ____________________ Date ____________
Citizenship ____________
(Country)
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Full Name of Sole/Fourth Inventor **John J. Bean** ______________________________
Inventor's Signature ________________________________ Date ____________________
Citizenship ____________________
(Country)
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Full Name of Sole/Fifth Inventor ____
Inventor's Signature ________________________________ Date ____________________
Citizenship ____________________
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Full Name of Sole/Sixth Inventor ____
Inventor's Signature ________________________________ Date ____________________
Citizenship ____________________
(Country)
Post Office Address (Business or Residence or P.O. Box) ______________________________
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(City and State of Residence)

Title 37, Code of Federal Regulations, Section 1.56
<u>Duty to Disclose Information Material to Patentability</u>

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclosure information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclosure all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) Prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) The closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made or record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application;

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.